WIRELESS LOCAL AREA NETWORK SYSTEM
WITH MOBILE ACCESS POINT STATION DETERMINATION

Related Application

This application is based upon prior filed
copending provisional application Serial No. 60/257,022
filed December 20, 2000.

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Field of the Invention

This invention relates to the field of
wireless local area networks (WLAN), and more
particularly, this invention relates to a wireless
10 local area network system having a mobile access point
station.

Background of the Invention

Wireless local area networks are becoming
15 more commonplace as the use of portable computers, such
as "laptop," "notebook," and "pen" computers become
increasingly common in office environments and other
locations. In most conventional wireless local area
networks, a number of access point base stations (or
20 access point stations as sometimes referred) form a
cellular network for communicating with wireless mobile
stations or other mobile devices. Each access point
station is typically connected to a network server,
such as part of an ethernet or other network
25 infrastructure. Any messages transmitted as wireless
communication signals are first transmitted to an
access point station instead of transmitted along

wireless stations. This type of centralized wireless communication using cells provides control over communications along existing wireless mobile devices. Typically, the wireless communication signals are a

5 spread spectrum communications signal, for example, a direct sequence spread spectrum signal, or a frequency hopping spread spectrum signal.

Although wireless local area networks are becoming more commonplace in offices and similar

10 environments, most wireless local area networks have fixed location access point stations that are positioned at the fixed and known location and used by a plurality of mobile devices that operate with and connect to the wireless local area network system

15 through the access point station. There are times when it may be advantageous to use a mobile access point station to extend the area of the wireless local area network or provide greater coverage in a specific area. Other reasons for using a mobile access point station

20 are known and could be suggested to those skilled in the art.

Most prior art wireless local area networks do not provide the capability of incorporating a mobile access point station into the network because the

25 wireless local area network has no location and processing capability to determine the location of an access point station operating in the wireless LAN environment. Although some wireless LAN systems provide for signal strength analysis of spread spectrum

30 signals to determine location of mobile devices, none of them provide any accurate location determination system of a mobile access point station that would be operative within the wireless infrastructure defined by other access point stations.

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Summary of the Invention

The present invention advantageously provides a wireless local area network system that determines the location of a mobile access point station that
5   receives and transmits communication signals within the wireless local area network and that could be operative with other mobile devices, such as location tags used in inventory control systems or other operative systems. The wireless local area network system
10 includes a plurality of access point stations at known locations that receive and transmit communication signals within the wireless local area network. A mobile access point station receives and transmits communication signals within the wireless local area
15 network. The location processor is operatively connected to each of the access point stations and operative to process communication signals transmitted from the mobile access point station and received in access point stations and determining which
20 communication signals are first-to-arrive signals based on a common timing signal and conducting differentiation of the first-to-arrive signals to locate the mobile access point station.

In yet another aspect of the present
25 invention, each access point station includes a plurality of mutually diverse antennas for detecting communication signals used in locating the mobile access point station. The location processor further comprises a matched filter correlator. This type of
30 correlator could include matched filter banks having parallel correlators that correlate a received communication signal with time offset versions of a reference spreading code. The location processor could include a plurality of processors for distributing the
35 processing capability.

In yet another aspect of the present invention, a wired local area network is operatively connected to an access point station to which a common timing signal is received and transmitted to other

5 access point stations. The common timing signal could include a wireless timing signal broadcast to each of the access point stations. Also, an access point station or mobile station could be chosen and operative for generating a common timing signal.

10 In yet another aspect of the present invention, at least three access point stations are used for determining the location of the mobile access point station.

In another aspect of the present invention, a

15 network management station (NMS) is operative under the Simple Network Management Protocol (SNMP. A Management Information Base (MIB) is operative with the network management station. The Management Information Base has deposited characteristics for objects corresponding

20 to access point stations and other devices associated with the wireless local area network system for allowing management control by the network management station.

In yet another aspect of the present

25 invention, a server receives data from the network management station and communicates management data about the wireless local area network to clients that access the server. In order to provide client access to the server via the worldwide web and internet, the

30 server comprises an HTTP server.

A method of the present invention locates a mobile access point station used in a wireless local area network and comprises the steps of receiving and transmitting communication signals along access point

35 stations of the wireless local area network that are

located at known positions. The method further
comprises the step of processing communication signals
received from a mobile access point station within a
location processor operatively connected to each access
5   point station and determining which communication
signals are first-to-arrive signals based on a common
timing signal and conducting differentiation of the
first-to-arrive signals to locate the mobile access
point station.
10

Brief Description of the Drawings

Other objects, features and advantages of the
present invention will become apparent from the
detailed description of the invention which follows,
15   when considered in light of the accompanying drawings
in which:

FIG. 1 is a high level block diagram of a
location determination system of the present invention
used for locating a mobile access point station.
20   FIG. 2 is a high level block diagram of one
example of the circuit architecture that can be used
with the present invention on the receive side.

FIG. 3 is another high level block diagram of
one example of the circuit architecture that can be
25   used for correlation-based RF signal processors in
accordance with the present invention.

Detailed Description of the Preferred Embodiments

The present invention will now be described
30   more fully hereinafter with reference to the
accompanying drawings, in which preferred embodiments
of the invention are shown. This invention may,
however, be embodied in many different forms and should
not be construed as limited to the embodiments set
35   forth herein. Rather, these embodiments are provided

so that this disclosure will be thorough and complete,
and will fully convey the scope of the invention to
those skilled in the art. Like numbers refer to like
elements throughout.

5   The present invention advantageously provides
a wireless local area network system that includes a
mobile access point station that is operative with a
plurality of access point stations at known locations,
which receive and transmit communication signals within
10   the wireless local area network among the wireless
access point stations with appropriate hand-off
capability and among various mobile devices. The
wireless access point stations each form a cellular
structure, as known to those skilled in the art. At
15   times, it may be desirable to add another access point
station into the network, such as to increase mobile
device capability or move an access point station to
another location. At these times, it is necessary to
"locate" the new position of the access point station
20   in the wireless local area network.

          The present invention also permits use of a
mobile access point station, but also permits its
position determination through the use of a location
processor operatively connected to each of the access
25   point stations and operative to process communication
signals transmitted from the mobile access point
stations and received in access point stations. The
location processor determines which communication
signals are first-to-arrive signals based on a common
30   timing signal and conducts differentiation of the
first-to-arrive signals to locate the mobile access
point station. Much of the technology and detection
capability as associated with the system and method of
the present invention can use the circuitry and
35   algorithms described in commonly assigned U.S. Patent

Nos. 5,920,287; 5,995,046; 6,121,926; 6,127,976; and
copending utility application Serial No. 09/997,282,
filed November 29, 2001, the disclosures which are all
hereby incorporated by reference in their entirety.

5   FIG. 1 illustrates a high level block diagram
of the system 10 of the present invention that
integrates not only a wireless local area network
system 12 with access point stations at known
positions, but also integrates a location determination

10 system as set forth in the above-identified and
incorporated by reference patents. As illustrated, one
access point station can be a standard, wireless local
area network access point station 14 that is connected
to a local area network 16 and a network server 18, as

15 known to those skilled in the art. Typically, the
local area network is an ethernet or other similar
network. The wireless local area network could be
interconnected by 10/100 ethernet or symbol S-24
wireless LAN.

20   A plurality of access point stations 20 with
the ability to locate a mobile access point station are
included and each define a cellular cell (shown as 21,
indicating the general vicinity of a cell) as part of a
wireless local area network. Each access point station

25 20 includes transmitter and receiver circuitry for
communicating with mobile devices (M) and receiving and
forwarding communication signals as packets to and from
mobile stations and among other access point stations.
Wireless mobile station techniques, in a preferred

30 embodiment, are spread spectrum wireless communication
signals. One of the access point stations is a
wireless mobile access point station 22 positioned at
an unknown location, as compared to other access point
stations that are at known locations. The mobile

access point station **22** receives and transmits
communication signals within the wireless local area
network **12**. A location processor **24** is operatively
connected to each of the access point stations **20** and

5 operative to process communication signals transmitted
from the mobile access point station **22** and received at
the access point stations to determine which
communication signals are first-to-arrive signals based
on a common timing signal, and conducting

10 differentiation of the first-to-arrive signals to
locate the mobile access point station. The processor
function could also be incorporated as distributed
processing with each access point station by
incorporating a processor at each access point station.

15 A common timing signal can be applied to each
access point station and to the location processor **24**
and can be provided by a wireless timing signal
broadcast to each of the access point stations **20**, such
as by a mobile station (M) located at a known location

20 or an access point station **20** that provides the common
timing signal. In yet another aspect of the present
invention, a common timing signal can be supplied
through a wired ethernet bus to a network server **18**
into an access point station and wirelessly transmitted

25 to other access point stations.

Each access point station could include a
plurality of mutually diverse antennas **26** used in
locating the mobile access point station. The
determination of the location for the mobile access

30 point station can use a communications signal, which
could include a separate location packet or pulse. It
could occur by processing part of the normal data or by
processing packets that are used specifically for
locating the mobile access point station. A

communication signal transmitted from the mobile access
point station **22** could include a spread spectrum
location pulse appended to the wireless communication
signal that could be of short duration (typically less

5 than one millisecond) spread spectrum transmission as a
location pulse, which is distinct and different from
the wireless local area network communication signal.
The location pulse could be appended to the falling
edge of the wireless communication signal or appended

10 to the beginning or rising edge of the communication
signal.

The mobile devices or stations in
communication with a mobile access point station could
transmit location data as appended pulses as set forth

15 in the incorporated by reference copending application
serial no. 09/997,282, filed November 29, 2001. The
mobile access point station could also add any
signaling and location information as determined by
those skilled in the art. Although direct sequence

20 spread spectrum communication signals are preferred,
including any location pulse, frequency hopping, chirp
or other spread spectrum signal techniques can also be
used. Location transmitters and location receives with
appropriate communications circuitry, as set forth in

25 the incorporated by reference patents and copending
patent application, can be included as part of any
mobile station or access point station as determined by
those skilled in the art.

As shown in FIG. 1, a Network Management

30 Station (NMS) **30** is operative under the Simple Network
Management Protocol (SNMP) and is operative with a
Management Information Base (MIB) **32**. Deposited
characteristics for objects corresponding to access
point stations and other devices associated with the

35 wireless local area network system allow management

control by the network management station **30**. The
wired local area network could also be incorporated
with an enterprise network and the network management
station could be operative to manage the network from a
5   central location and collect network statistics for
capacity planning. It is also possible to work with
agents that monitor devices as the objects and report
information to the network management station **30**. Any
devices that are not SNMP-compliant could be linked to
10   the network management station by a proxy agent. The
network management station **30** can provide information
display, communicate with agents, perform information
filtering and control capabilities. The management
information base **32** contains a description of SNMP-
15   compliant objects on the network and the kids of
management information they provide.

         For purposes of description, the type of
location circuits, algorithms, and associated functions
that can be used with the present invention, such as
20   the location processor functions and any location
receivers and location transmitters, are set forth in
the incorporated by reference patents. For purposes of
description, FIGS. 2 and 3 describe representative
examples of circuit architectures that can be used for
25   representative access point station and location
processor.

         FIG. 2 diagrammatically illustrates one type
of circuitry configuration of a respective architecture
for "reading" associated communication signals or a
30   pulse (a "blink") used for location determination
signals, such as signals emitted from a mobile station
(M) or generally the mobile access point station that
is to be located in the present invention. An antenna
210 senses appended transmission bursts or other
35   signals from the mobile access point station to be

located. The antenna in this aspect of the invention
could also be omnidirectional and circularly polarized
and coupled to a power amplifier **212**, whose output is
filtered by a bandpass filter **214**. Respective I and Q
5 channels of the bandpass filtered signal are processed
in associated circuits corresponding to that coupled
downstream of filter **214**. To simplify the drawing only
a single channel is shown.

A respective bandpass filtered I/Q channel is
10 applied to a first input **221** of a down-converting mixer
223. Mixer **223** has a second input **225** coupled to
receive the output of a phase-locked local IF
oscillator **227**. IF oscillator **227** is driven by a
highly stable reference frequency signal (e.g., 175
15 MHz) coupled over a (75 ohm) communication cable **231**
from a control processor. The reference frequency
applied to phase-locked oscillator **227** is coupled
through an LC filter **233** and limited via limiter **235**.

The IF output of mixer **223**, which may be on
20 the order of 70 MHz, is coupled to a controlled
equalizer **236**, the output of which is applied through a
controlled current amplifier **237** and applied to
communication cable **231** to a communication signal
processor, which could be associated processor **32,32a**.
25 The communication cable **231** also supplies DC power for
the various components of the location receiver by way
of an RF choke **241** to a voltage regulator **242**, which
supplies the requisite DC voltage for powering an
oscillator, power amplifier and analog-to-digital units
30 of the receiver.

The amplitude of the (175 MHZ) reference
frequency supplied by the communications control
processor to the phase locked local oscillator **227**
implies the length of any communication cable **231** (if

used) between the location processor and a receiver,
such as if part of an access point station. This
magnitude information can be used as control inputs to
equalizer **236** and current amplifier **237**, so as to set
5 gain and/or a desired value of equalization, that may
be required to accommodate any length of a
communication cable (if used). For this purpose, the
magnitude of the reference frequency may be detected by
a simple diode detector **245** and applied to respective
10 inputs of a set of gain and equalization comparators
shown at **247**. The outputs of comparators are quantized
to set the gain and/or equalization parameters.

FIG. 3 diagrammatically illustrates the
architecture of a correlation-based, RF signal
15 processor as part of a processor to which the output of
a respective RF/IF conversion circuit of FIG. 2 can be
coupled for processing the output and determining
location. The correlation-based RF signal processor
correlates spread spectrum signals detected by its
20 associated receiver with successively delayed or offset
in time (by a fraction of a chip) spread spectrum
reference signal patterns, and determines which spread
spectrum signal received by a receiver of an access
point station is the first-to-arrive corresponding to a
25 location pulse or communications signal from the
transmitter of a mobile access point station as part of
the communications signal that has traveled over the
closest observable path between the mobile access point
station and the fixed location access point station.

30 Because each receiver can be expected to
receive multiple signals from the mobile access point
station **22**, due to multipath effects caused by the
signal transmitted by the mobile access point station
being reflected off various objects/surfaces between
35 the mobile access point station and the receiver of

other known access point stations **20**, the correlation
scheme ensures identification of the first observable
transmission, which is the only signal containing valid
timing information from which a true determination can
5 be made of the distance from the station to the
receiver.

For this purpose, as shown in FIG. 3, the RF
processor employs a front end, multi-channel digitizer
300, such as a quadrature IF-baseband down-converter
10 for each of an N number of receivers. The quadrature
baseband signals are digitized by associated analog-to-
digital converters (ADCs) **272I** and **272Q**. Digitizing
(sampling) the outputs at baseband serves to minimize
the sampling rate required for an individual channel,
15 while also allowing a matched filter section **305**, to
which the respective channels (reader outputs) of the
digitizer **300** are coupled to be implemented as a
single, dedicated functionality ASIC, that is readily
cascadable with other identical components to maximize
20 performance and minimize cost.

This provides an advantage over bandpass
filtering schemes, which require either higher sampling
rates or more expensive ADCs that are capable of
directly sampling very high IF frequencies and large
25 bandwidths. Implementing a bandpass filtering approach
typically requires a second ASIC to provide an
interface between the ADCs and the correlators. In
addition, baseband sampling requires only half the
sampling rate per channel of bandpass filtering
30 schemes.

The matched filter section **305** may contain a
plurality of matched filter banks **307**, each of which is
comprised of a set of parallel correlators, such as
described in the above identified, incorporated by

reference '926 patent. A PN spreading code generator could produce a PN spreading code (identical to that produced by the PN spreading sequence generator of the location transmitter). The PN spreading code produced

5 by PN code generator is supplied to a first correlator unit and a series of delay units, outputs of which are coupled to respective ones of the remaining correlators. Each delay unit provides a delay equivalent to one-half a chip. Further details of the

10 parallel correlation are found in the incorporated by reference '926 patent.

As a non-limiting example, the matched filter correlators may be sized and clocked to provide on the order of 4×10^6 correlations per epoch. By continuously

15 correlating all possible phases of the PN spreading code with an incoming signal, the correlation processing architecture effectively functions as a matched filter, continuously looking for a match between the reference spreading code sequence and the

20 contents of the incoming signal. Each correlation output port **328** is compared with a prescribed threshold that is adaptively established by a set of "on-demand" or "as needed" digital processing units 340-1, 340-2, ..., 340-K. One of the correlator outputs **328** has a

25 summation value exceeding the threshold in which the delayed version of the PN spreading sequence is effectively aligned (to within half a chip time) with the incoming signal.

This signal is applied to a switching matrix

30 **330**, which is operative to couple a "snapshot" of the data on the selected channel to a selected digital signal processing unit **340-i** of the set of digital signal processing units **340**. The mobile access point station can "blink" or transmit location pulses

35 randomly, and can be statistically quantified, and

thus, the number of potential simultaneous signals over
a processor revisit time could determine the number of
such "on-demand" digital signal processors required. A
processor would scan the raw data supplied to the
5   matched filter and the initial time tag. The raw data
is scanned at fractions of a chip rate using a separate
matched filter as a co-processor to produce an
auto-correlation in both the forward (in time) and
backwards (in time) directions around the initial
10   detection output for both the earliest (first
observable path) detection and other buried signals.
The output of the digital processor is the first path
detection time, threshold information, and the amount
of energy in the signal produced at each receiver's
15   input, which is supplied to and processed by the time-
of-arrival-based multi-lateration processor section
400.

Processor section **400** uses a standard multi-
lateration algorithm that relies upon time-of-arrival
20   inputs from at least three detectors of the access
point stations **20** to compute the location of the mobile
access point station **22**. The algorithm may be one
which uses a weighted average of the received signals.
In addition to using the first observable signals to
25   determine object location, the processor also can read
any data read out of a memory for the mobile access
point station (or mobile device if applicable) and
superimposed on the transmission. Object position and
parameter data can be downloaded to a data base where
30   object information is maintained. Any data stored in a
mobile station memory may be augmented by altimetry
data supplied from a relatively inexpensive,
commercially available altimeter circuit. Further
details of such circuit are found in the incorporated
35   by reference '926 patent.

It is also possible to use an enhanced
circuit as shown in the incorporated by reference '926
patent to reduce multipath effects, by using dual
antenna (as shown generally with dual antenna in
5   FIG. 1) and providing spatial diversity-based
mitigation of multipath signals. In such systems, the
antennas of each location receiver at an access point
station are spaced apart from one another by a distance
that is sufficient to minimize destructive multipath
10   interference at both antennas simultaneously, and also
ensure that the antennas are close enough to one
another so as to not significantly affect the
calculation of the location of the object by the
downstream multi-lateration processor.

15   The multi-lateration algorithm executed by
the location processor **24** is modified to include a
front end subroutine that selects the earlier-to-arrive
outputs of each of the detector pairs as the value to
be employed in the multi-lateration algorithm. A
20   plurality of auxiliary "phased array" signal processing
paths can be coupled to the antenna set (e.g., pair),
in addition to the paths containing the directly
connected receivers and their associated first arrival
detectors that feed the triangulation locator
25   processor. Each respective auxiliary phased array path
is configured to sum the energy received from the two
antennas in a prescribed phase relationship, with the
energy sum being coupled to associated units that feed
a processor as a triangulation processor.

30   The purpose of a phased array modification is
to address the situation in a multipath environment
where a relatively "early" signal may be canceled by an
equal and opposite signal arriving from a different
direction. It is also possible to take advantage of an
35   array factor of a plurality of antennas to provide a

reasonable probability of effectively ignoring the destructively interfering energy. A phased array provides each site with the ability to differentiate between received signals, by using the "pattern" or
5   spatial distribution of gain to receive one incoming signal and ignore the other.

The multi-lateration algorithm executed by the location processor could include a front end subroutine that selects the earliest-to-arrive output
10 of its input signal processing paths and those from each of the signal processing paths as the value to be employed in the multi-lateration algorithm (for that receiver site). The number of elements and paths, and the gain and the phase shift values (weighting
15 coefficients) may vary depending upon the application.

It is also possible to partition and distribute the processing load by using a distributed data processing architecture as described in the incorporated by reference 6,127,976 patent and
20 generally shown by the block diagram in FIG. 1, where multiple processing units **24a, 24b, 24c** are shown. This architecture can be configured to distribute the workload over a plurality of interconnected information handling and processing subsystems. Distributing the
25 processing load enables fault tolerance through dynamic reallocation.

The front end processing subsystem can be partitioned into a plurality of detection processors, so that data processing operations are distributed
30 among sets of detection processors. The partitioned detection processors are coupled in turn through distributed association processors to multiple location processors. For mobile access point station (or mobile device) detection capability, each receiver could also
35 be equipped with a low cost omnidirectional antenna,

that provides hemispherical coverage within the
monitored environment.

A detection processor filters received energy
to determine the earliest time-of-arrival energy
5   received for a transmission, and thereby minimize
multi-path effects on the eventually determined
location of a mobile device. The detection processor
demodulates and time stamps all received energy that is
correlated to known spreading codes of the
10 transmission, so as to associate a received location
pulse with only one mobile. It then assembles this
information into a message packet and transmits the
packet as a detection report over a communication
framework to one of the partitioned set of association
15 processors, and then de-allocates the detection report.

A detection processor to association control
processor flow control mechanism equitably distributes
the computational load among the available association
processors, while assuring that all receptions of a
20 single location pulse transmission, whether they come
from one or multiple detection processors, are directed
to the same association processor.

The flow control mechanism uses an
information and processing load distribution algorithm,
25 to determine which of the association processors is to
receive the message, and queues the message on a
prescribed protocol coupling socket connecting the
detection processor to the destination association
processor. To select a destination association
30 processor, the information and processing load
distribution algorithm may include a prime number-based
hashing operation to ensure a very uniform distribution
of packets among association processors. In addition,
to provide relatively even partitioning in the case of
35 widely varying transmission rates, the hashing

algorithm may use a sequence number contained in each
transmission.

Each association processor can organize its
received message packets by identification (ID) and
5   time-of-arrival (TOA), and stores them as association
reports. The association processor compresses the data
within the association report, transmits that
information over an association communication process
of the communication framework to one of a plurality of
10 distributed location processors, and then de-allocates
the association report.

In order to deliver all association reports
that have been generated for an individual mobile
access point station (or mobile device) to a single
15 destination location processor, the association
communication process of the communication framework
may employ the same information and processing load
distribution algorithm executed by the detection
communication process of the communication framework.
20 Each location processor determines the geographical
location of a mobile access point station (or mobile
device) using the time-of-arrival measurement
information originally sourced from the detection
processors. The specific algorithm employed for
25 location determination matches the number of arrival
time measurements with whatever a priori information is
available.

To locate a mobile access point station (or
mobile device), a location processor may employ all
30 available diversity information associated with the
mobile of interest, including, but not limited to the
station ID (if any), any data contained in the
transmission and metrics indicating confidence it these
values. It then forwards a location report containing
35 this information over a location communication process

to an asset management data base. A location estimate
may be derived from the measured time-of-arrival
information in a received association report packet,
using a differential time-of-arrival algorithm, such as
5   a hyperbolic geometry-based function.

It is also possible to use a wireless local
area network (WLAN) spread spectrum waveform to perform
the geo-location function of the present invention.
The assumption is that the wireless communication
10   signal, as a spread spectrum signal, has a high signal-
to-noise ratio with reasonable power levels. The
leading edge of this communication signal can be
detected to a high accuracy and this information used
with the algorithms as described before to provide
15   relative time of arrival information for subsequent
processing. It is possible to use edge detector
circuitry 60 as part of an access point station 20
having a wireless local area network (WLAN) receiver.
It is also possible to have a timing signal from a
20   known location or unknown location. Other component
locations could be known, of course. For example, some
wireless local area network (WLAN) transmitters have
known locations to enable the use of the algorithm when
an access point station or mobile station location is
25   known.

It is also known that the communications
signal as a spread spectrum communications signal can
have sufficient bandwidth to provide useful time
accuracy. For example, a 50 MHz bandwidth could
30   provide approximately 5 nanoseconds of timing accuracy
that is about 5 feet of accuracy using much of the
technology and teachings described before. It is
possible to use a correlator operative as a functional
spread spectrum matched filter to enable a higher
35   quality estimate with integration over many chips of

the spread spectrum transmission. It is possible to use a matched filter that spans multiple symbols and improve accuracy by collecting more energy in the filter prior to leading edge detection.

5   Many modifications and other embodiments of the invention will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the

10 invention is not to be limited to the specific embodiments disclosed, and that the modifications and embodiments are intended to be included within the scope of the dependent claims.